(양식 1)

【 고분자학회 학회상 포상 지원서 】

[표지]

<table>
<tr><td>공모분야</td><td colspan="5">신진학술상</td></tr>
<tr><td rowspan="5">지원자
인적사항</td><td rowspan="2">성 명</td><td>한 글</td><td>조창순</td><td rowspan="2">영 문</td><td rowspan="2">Changsoon Cho</td></tr>
<tr><td>한 자</td><td>**曺彰純**</td></tr>
<tr><td rowspan="3">소속기관</td><td>기관명</td><td colspan="3">POSTECH</td></tr>
<tr><td>부서명
(학과명)</td><td>신소재공학과</td><td>직위/직급</td><td>조교수</td></tr>
<tr><td>주 소</td><td colspan="3">(37673) 경북 포항시 남구 청암로 77
포항공과대학교 신소재공학과</td></tr>
<tr><td>업적요지</td><td colspan="5">본 지원자는 2017년에 유기태양전지 및 OLED 연구를 주제로 박사학위를 취득한 이후 영국 캐번디시 연구소와 독일 드레스덴 공대를 거쳐 2023년 포항공과대학교 조교수로 부임한 신진연구자입니다. 최근에는 유기물, 양자점, 유무기복합 페로브스카이트 등 차세대 나노박막 광전소재가 가진 독특한 광물리 특성을 분석하고, 이를 활용하여 태양전지, 발광소자 등에 응용하는 연구를 주로 수행해오고 있습니다. 고분자학회는 2014년 학생회원으로 첫 인연을 맺었고, 교원이 된 후로는 춘계/추계 학술대회, KJF 및 Fpi 등 국제행사, 분자전자 심층토론회 등 주요 행사들에 빠짐없이 참여하며 활동하고 있습니다.

박사학위 취득 후 본 연구자는 2022년 세계 최초의 4차원 전하확산 이미징 기술을 개발하였고 (*Nature Materials*, 2022), 2020년 재흡광 발광소재의 광모델을 처음으로 정립하는 등 (*Nature Communications*, 2020) 기초과학과 테크놀로지의 연결고리 역할을 할 수 있는 연구들에 많은 초점을 맞춰왔습니다. 소재의 광특성에 대한 이해를 바탕으로 소자 및 시스템의 성능을 향상 시키고자 하는 이같은 노력들은 근래에 좋은 연구성과들로 이어지고 있습니다. 최근에는 차세대 광발광 디스플레이의 성능향상을 위한 소자설계전략을 제시하였고 (*Nature Electronics*, accepted), 국내외 다양한 그룹과의 협업을 통해 세계 최고효율의 OLED, 페로브스카이트 LED, 페로브스카이트 태양전지 등의 개발에 기여해왔습니다 (*Nature*, 2022; *Nature*, 2023; *Nature*, 2024; *Nature Photonics*, 2024; *Nature Communications*, 2024).</td></tr>
<tr><td colspan="6">상기와 같이 고분자학회 학회상 포상을 지원합니다.

2025. 8. 20

기관명 : POSTECH
직 위 : 조교수
지원자 : 조 창 순 (직인)</td></tr>
</table>

(양식 2)

1. 인적사항

가. 학력사항 (대학교 이상만 기재)

기　　간	학 교 명	전공 및 학위, 지도교수
2007.2 - 2011.2	KAIST	학사, 전기및전자공학과
2011.3 - 2013.2	KAIST	석사, EEWS대학원 (이정용)
2013.3 - 2017.2	KAIST	박사, EEWS대학원 (이정용)

나. 경력사항 (5개 이내 기재)

기　　간	기관명(직위, 직책 등)
2023.4 - Present	POSTECH 조교수
2021.2 – 2023.3	Cavendish Laboratory, University of Cambridge Postdoc Research Associate
2019.5 – 2021.1	Technical University of Dresden Humboldt Research Fellow
2018.5 – 2019.4	Cavendish Laboratory, University of Cambridge Visiting Researcher
2017.3 – 2019.4	KAIST 박사후연구원

다. 수상경력 (최근 3년 이내)

일　자	수 상 내 용	시 상 기 관

2. 수상후보자 추천인단 명부

성 명	전 공 분 야	세부전공 분야	소 속	비고
고민재	고분자/재료	고분자&에너지소재	한양대학교	
김봉수	화학	고분자&유기반도체	UNIST	
정운룡	화학공학/재료	고분자&유연소자	POSTECH	

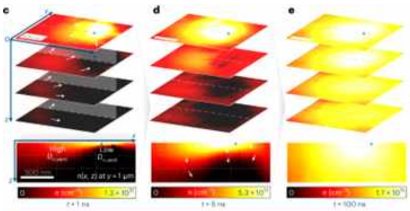
3. 대표논문의 연구업적 요약서

포항공과대학교 신소재공학과 조창순 교수는 KAIST에서 유기태양전지 및 유기발광소자 연구로 박사학위를 취득하고 2023년 포항공과대학교에 부임한 신진연구자로써, 그동안 주/교신저자 21편을 비롯하여 50편 이상의 SCI 논문을 출판하였음 (h-index 34). 본 연구자는 연간 피인용수가 매년 빠르게 상승하고 있으며, 최근 3년간 참여한 11편 논문들의 평균 영향력 지수(IF)가 30.7에 달하는 등 높은 학문적 수월성과 성장 잠재력을 나타내고 있음. 본 연구자의 주 연구업적은 다음과 같이 요약할 수 있음. (3건의 대표논문은 밑줄로 표시)

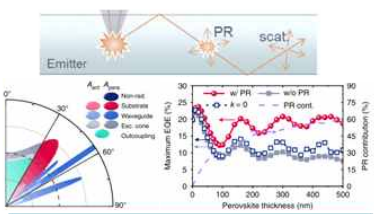
- **[나노소재 분광분석]** 본 연구자는 시분해 현미경과 스펙트럼 분석을 결합하여 나노박막 내부에서 전하들의 이동도를 평면 방향은 물론 깊이 방향까지 동시에 추적하고 입체적으로 표현할 수 있는 4차원 (*x, y, z, t*) 발광 다이나믹스 이미징 기술을 세계 최초로 개발하였음 (*Nat. Mater.*, 2022). 이는 소재의 단일 특성으로 여겨졌던 전하확산계수를 공간의 함수로 표현할 수 있게 되었다는 점에서 광전소재에 대한 이해의 폭을 크게 넓힐 수 있는 계기가 되었으며, 페로브스카이트 태양전지를 비롯한 다양한 고성능 유기/무기 나노박막 광전소자들의 구동원리 규명에 기여하였음. 또한 공간분해 형광분석을 통해 페로브스카이트 소재 내부의 광자재활용 현상을 규명하고 (*Nat. Commun.*, 2020; *Sci. Adv.*, 2021), OLED 이중항 유기발광소재의 각도분해 형광분석을 통해 엑시톤 및 분자들의 배열 비등방성을 정량화 하는 등 (*Nat. Photon.*, 2024) 다양한 분광분석 연구를 수행함.

- **[소자설계 및 시뮬레이션]** 또한 본 연구자는 광학 시뮬레이션 등 소자 설계 분야에서 뛰어난 역량을 인정받고 있음. 2020년에는 빛의 재흡수 특성을 고려할 수 없었던 기존 OLED 시뮬레이션의 한계를 극복하고 유기물, 페로브스카이트, 양자점 등에 골고루 활용될 수 있는 범용 재흡광 발광소재 광학 모델을 세계 최초로 수립하여 발표하였으며 (*Nat. Commun.*, 2020; *Adv. Sci.*, 2021), 이를 통해 다양한 형태의 소자구조를 설계 및 분석 해오고 있음. 논문 발표 이후 5년이 지난 지금까지도 본 연구자는 재흡광 발광소재의 발광특성 시뮬레이션에 있어 최고의 전문성을 인정받고 있음.

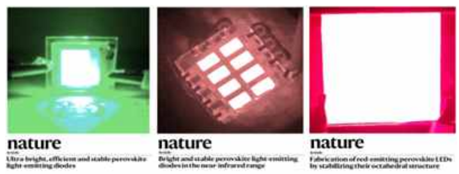
- **[분자전자 및 나노광전소자]** 본 지원자는 학위과정 때부터 유기태양전지 및 OLED의 효율을 높여줄 수 있는 플라스모닉스 및 광학기술들에 대한 연구를 수행해왔음. 또한 차별성 있는 소자설계 기술을 기반으로 다양한 그룹과의 협업을 통해 세계 최고 성능의 근적외선 유기물 LED (*Nat. Photon.*, 2024)와 세계 최고 효율의 녹색 (*Nature*, 2022), 적색 (*Nature*, 2024), 및 근적외선 (*Nature*, 2023; *Adv. Funct. Mater.*, 2024) 페로브스카이트 LED, 고발광효율 페로브스카이트 태양전지 (*Sci. Adv.*, 2021; *Nat. Commun.*, 2024) 등 다양한 최고 성능 소자개발 연구에 참여해왔음. 교원 임용 후에는 백라이트 위에 색변환층을 도포하는 형태의 광발광 디스플레이 개발을 위해 많은 연구를 수행하고 있으며, 특히 최근에는 페로브스카이트 발광소재의 색변환층으로써의 잠재력을 밝히는 한편, 차세대 광발광 디스플레이의 성능 극대화를 위한 다양한 광학 전략들을 발표하였음. (*Nat. Elect. accepted*)



세계 최초의 4차원 전하확산 이미징 기술



세계 최초의 재흡광 발광소재 광학모델



최고효율 나노박막 LED 및 태양전지 개발에 기여
& 차세대 디스플레이를 위한 광학전략 제시

4. 연구개발 실적

(1) 업적 총괄 (단위:건)

논문	SCIE 등재 학술지				h-index		
	제1저자	공동저자	교신저자	소계	Web of Science	Google Scholar	SCOPUS
	19	30	6 (1저 4건 포함)	51	34	30	28

특허	국내	국외	기술이전	연구 보고서	저서
	등록	등록			
	6	-	-	-	-

*h-index 증빙자료(화면캡처본) 별첨.

(2) 대표논문 목록

제 목	발표지명	Impactor factor	발표 년도	역할(저자)	저자수 (명)	피인용 횟수
Perovskites for next-generation colour conversion displays	Nature Electronics	40.9	accepted	교신저자	9	-
Efficient Vertical Charge Transport in Polycrystalline Halide Perovskites Revealed by Four-Dimensional Tracking of Charge Carriers	Nature Materials	38.5	2022	주저자	13	62
The role of photon recycling in perovskite light-emitting diodes	Nature Communications	15.7	2020	주저자	8	202

*제목 및 저자를 확인할 수 있는 증빙자료 별첨.

(3) 총괄연구업적 목록

☐ 학술지 논문 - SCIE 등재지에 한함

제 목	발표지명	Impactor factor	발표 년도	역할(저자)	저자수(명)	피인용 횟수
Perovskites for next-generation colour conversion displays,	Nature Electronics	40.9	accepted	교신	9	-
Discriminating Circular Polarization of Light: Left or Right?,	Light: Science & Applications	23.4	2025	교신	2	0
Enhanced Photon Recycling Enables Efficient Perovskite Light-Emitting Diodes,	Advanced Functional Materials	19.0	2024	주저자	5	4
Efficient near-infrared organic light-emitting diodes with emission from spin doublet excitons,	Nature Photonics	32.9	2024	공동	15	25
Fabrication of red-emitting perovskite LEDs by stabilizing their octahedral structure,	Nature	48.5	2024	공동	19	155
Quantum barriers engineering toward radiative and stable perovskite photovoltaic devices,	Nature Communications	15.7	2024	주저자	16	13
Stabilizing Single-Source Evaporated Perovskites with Organic Interlayers for Amplified Spontaneous Emission,	Advanced Optical Materials	7.2	2024	공동	14	7
Bright and stable perovskite light-emitting diodes in the near-infrared range,	Nature	48.5	2023	공동	22	322
Efficient Vertical Charge Transport in Polycrystalline Halide Perovskites Revealed by Four-Dimensional Tracking of Charge Carriers,	Nature Materials	38.5	2022	주저자	13	62
Ultra-bright, Efficient and Stable Perovskite Light-Emitting Diodes,	Nature	48.5	2022	공동	13	773
Optical Properties of Perovskite-Organic Multiple Quantum Wells,	Advanced Science	14.1	2022	공동	13	18
Effects of Photon Recycling and Scattering to Overcome the Efficiency Limit of Perovskite Solar Cells,	Science Advances	12.5	2021	주저자(교신)	7	42
23.7% Efficient Inverted Perovskite Solar Cells by	Science Advances	12.5	2021	공동	8	384

Dual Interfacial Modification,						
Control of Emission Characteristics of Perovskite Lasers through Optical Feedback	Advanced Photonics Research	3.9	2021	주저자	7	7
Electrical Pumping of Perovskite Diodes: Toward Stimulated Emission,	Advanced Science	14.1	2021	주저자(교신)	9	44
Small grains as recombination hot spots in perovskite solar cells,	Matter	17.5	2021	공동	9	152
Computational Study of Dipole Radiation in Re-Absorbing Perovskite Semiconductors for Optoelectronics,	Advanced Science	14.1	2021	주저자(교신)	2	35
Manufacturing of Compound Parabolic Concentrator Devices Using an Ultra-fine Planing Method for Enhancing Efficiency of a Solar Cell,	International Journal of Precision Engineering and Manufacturing-Green Technology	5.6	2020	공동	9	7
Controlling and Optimizing Amplified Spontaneous Emission in Perovskites,	ACS Applied Materials & Interfaces	8.2	2020	주저자(교신)	6	48
Enhanced bendability of nanostructured metal electrodes: effect of nanoholes and their arrangement,	Nanoscale	5.1	2020	주저자	5	8
Thermally evaporated methylammonium-free perovskite solar cells,	Journal of Materials Chemistry C	5.1	2020	공동	11	67
The role of photon recycling in perovskite light-emitting diodes,	Nature communications	15.7	2020	주저자	8	202
Long-range ballistic propagation of carriers in methylammonium lead iodide perovskite thin films,	Nature Physics	18.4	2020	공동	12	137
Multi-bandgap Solar energy conversion via combination of Microalgal photosynthesis and Spectrally Selective photovoltaic cell,	Scientific reports	3.9	2019	주저자	9	28
Sequentially deposited		26.0	2019	공동	19	78

versus conventional nonfullerene organic solar cells: interfacial trap states, vertical stratification, and exciton dissociation,	Advanced Energy Materials					
Highly efficient (> 10%) flexible organic solar cells on PEDOT-free and ITO-free transparent electrodes,	Advanced Materials	26.8	2019	공동	5	118
Study of Optical Configurations for Multiple Enhancement of Microalgal Biomass Production,	Scientific Reports	3.9	2019	주저자	7	27
Columnar-structured Low-concentration Donor molecules in Bulk Heterojunction Organic Solar Cells,	ACS Omega	4.3	2018	공동	10	17
Two-dimensional sheet resistance model for polycrystalline graphene with overlapped grain boundaries,	FlatChem	6.2	2018	공동	8	8
Broadband light trapping strategies for quantum-dot photovoltaic cells (>10%) and their issues with the measurement of photovoltaic characteristics,	Scientific Reports	3.9	2017	주저자	5	13
Rationally Designed Donor-Acceptor Random Copolymers with Optimized Complementary Light Absorption for Highly Efficient All-Polymer Solar Cells,	Advanced Functional Materials	19.0	2017	공동	12	39
Self-Organization of Polymer Additive, Poly(2-vinylpyridine) via One-Step Solution Processing to Enhance the Efficiency and Stability of Polymer Solar Cells,	Advanced Energy Materials	26.0	2017	공동	7	36
Effects of Backbone Planarity and Tightly Packed Alkyl Chains in the Donor-Acceptor Polymers for High Photostability,	Macromolecules	5.2	2016	공동	12	46
Improved Internal Quantum Efficiency and Light-Extraction Efficiency of Organic Light-Emitting	ACS Applied Materials &	8.2	2016	주저자	7	42

Diodes via Synergistic Doping with Au and Ag Nanoparticles,	Interfaces					
Optical study of thin-film photovoltaic cells with apparent optical path length,	Journal of Optics	2.7	2016	주저자	3	10
Fabrication of high aspect ratio nanogrid transparent electrodes via capillary assembly of Ag nanoparticles,	Nanoscale	5.1	2016	공동	6	36
Self-Supplied Nano-Fusing and Transferring Metal Nanostructures via Surface Oxide Reduction,	ACS Appl. Mater. Interfaces	8.2	2016	공동	8	30
Toward Perfect Light Trapping in Thin-Film Photovoltaic cells: Full Utilization of Dual Characteristics of Light,	Advanced Optical Materials	7.2	2015	주저자	7	30
Design of asymmetrically textured structure for efficient light trapping in building integrated photovoltaics,	Organic electronics	3.0	2015	주저자	3	18
Development of highly transparent Pd-coated Ag nanowire electrode for display and catalysis applications,	Applied Surface Science	6.9	2015	공동	7	17
Nanoimprinting-induced nanomorphological transition in polymer solar cells: enhanced electrical and optical performance,	ACS Nano	16.0	2015	공동	8	39
Efficient Organic Photovoltaics Utilizing Nanoscale Heterojunctions in Sequentially Deposited Polymer/fullerene Bilayer,	Scientific Reports	3.9	2015	공동	8	66
ITO-free highly bendable and efficient organic solar cells with Ag nanomesh/ZnO hybrid electrodes,	Journal of Materials Chemistry A	9.5	2015	공동	9	69
Enhancement of growth and lipid production from microalgae using fluorescent paint under the solar radiation,	Bioresource Technology	9.0	2014	공동	4	62
Highly Transparent Au coated Ag Nanowire Transparent Electrode with Reduction in Haze,	ACS Applied Materials & Interfaces	8.2	2014	공동	6	83
Au@Ag Core-Shell Nanocubes for Efficient	ACS Nano	16.0	2014	공동	8	280

Plasmonic Light Scattering Effect in Low Bandgap Organic Solar Cells,						
Surface Plasmon Assisted High Performance Top-Illuminated Polymer Solar Cells with Nanostructured Ag Rear Electrodes,	Journal of Materials Chemistry A	9.5	2014	공동	8	24
Highly Efficient Top-Illuminated Flexible Polymer Solar Cells with a Nanopatterned 3-Dimensional Microresonant Cavity,	Small	10.3	2014	공동	7	29
Random and V-groove texturing for efficient light trapping in organic photovoltaic cells,	Solar Energy Materials and Solar Cells	9.5	2013	주저자	10	96
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□ **등록**된 국내외 특허

제 목	등록번호	등록년도	등록처	역할
형상 가변형 복합 포물형 태양광 집광기	10-2132523	2020	대한민국	공동발명자
마이크로 광학 구조를 이용한 4단자 다중 접합 태양전지	10-2095100	2020	대한민국	공동발명자
구조체 배열을 이용한 무손실 대면적 태양광 발전 시스템 및 그 제조 방법	10-1976918	2019	대한민국	공동발명자
전기 및 바이오연료의 동시 생산을 위한 혼성 태양광 에너지 변환 기술	10-1761063	2017	대한민국	공동발명자
텍스쳐링 표면을 가진 투명 필름을 이용한 유기 박막 태양전지	10-1406882	2014	대한민국	공동발명자
태양 전지의 전력 변환 효율 증가를 위한 집광기 일체형 빛 가둠 장치	10-1283912	2013	대한민국	공동발명자

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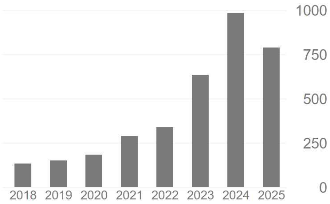

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증빙자료 – 대표논문 1

Perovskites for next-generation colour conversion displays

Jihun Kim[1,6], Eui Dae Jung[1,6], Jeonghwan You[2], Jeongjae Lee[3], Bum Chan Park[1], Henry J. Snaith[4], Richard H. Friend[5], Changsoon Cho[2*], Bo Ram Lee[1*]

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Perovskites for next-generation colour conversion displays
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electronics@nature.com
07-24 (목) , 00:26
Changsoon Cho (조창순)

전체 회신

Dear Professor Cho,

Please find below a copy of the decision letter for your manuscript "Perovskites for next-generation colour conversion displays", which has now been accepted for publication in Nature Electronics.

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Best wishes,

Dr Owain Vaughan
Chief Editor
Nature Electronics

Subject: Decision on Nature Electronics manuscript NATELECTRON-25020328B

Dear Professor Lee,

I am pleased to inform you that your Perspective, "Perovskites for next-generation colour conversion displays", has now been accepted for publication in Nature Electronics.

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증빙자료 - 대표논문 2

nature materials

Article

https://doi.org/10.1038/s41563-022-01395-y

Efficient vertical charge transport in polycrystalline halide perovskites revealed by four-dimensional tracking of charge carriers

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Check for updates

Changsoon Cho[1], Sascha Feldmann[1,2], Kyung Mun Yeom[3], Yeoun-Woo Jang[4,5], Simon Kahmann[1,6], Jun-Yu Huang[1,7], Terry Chien-Jen Yang[1,6], Mohammed Nabaz Taher Khayyat[3], Yuh-Renn Wu[7], Mansoo Choi[4,5], Jun Hong Noh[3,8], Samuel D. Stranks[1,6] & Neil C. Greenham[1]

Fast diffusion of charge carriers is crucial for efficient charge collection in perovskite solar cells. While lateral transient photoluminescence microscopies have been popularly used to characterize charge diffusion in perovskites, there exists a discrepancy between low diffusion coefficients measured and near-unity charge collection efficiencies achieved in practical solar cells. Here, we reveal hidden microscopic dynamics in halide perovskites through four-dimensional (directions *x*, *y* and *z* and time *t*) tracking of charge carriers by characterizing out-of-plane diffusion of charge carriers. By combining this approach with confocal microscopy, we discover a strong local heterogeneity of vertical charge diffusivities in a three-dimensional perovskite film, arising from the difference between intragrain and intergrain diffusion. We visualize that most charge carriers are efficiently transported through the direct intragrain pathways or via indirect detours through nearby areas with fast diffusion. The observed anisotropy and heterogeneity of charge carrier diffusion in perovskites rationalize their high performance as shown in real devices. Our work also foresees that further control of polycrystal growth will enable solar cells with micrometres-thick perovskites to achieve both long optical path length and efficient charge collection simultaneously.

The diffusion of charge carriers plays an important role in solar cells, to transport holes and electrons across photoactive layers. Among various techniques for characterizing diffusivity[1–7], photoluminescence (PL) microscopy is a popular and straightforward method to visualize the diffusive motion of charges. Several groups have used this technique to quantify free charge carrier diffusivities (D_n) of three-dimensional (3D) perovskite films and reported those to be on the order of 10^{-2} cm^2 s^{-1} (refs. [5,8,9]), one to two orders lower than those for perovskite single

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증빙자료 - 대표논문 3

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ARTICLE

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The role of photon recycling in perovskite light-emitting diodes

Changsoon Cho[1,2,4], Baodan Zhao[1,3], Gregory D. Tainter[1], Jung-Yong Lee[2], Richard H. Friend[1], Dawei Di[1,3*], Felix Deschler[1,5*] & Neil C. Greenham[1*]

Perovskite light-emitting diodes have recently broken the 20% barrier for external quantum efficiency. These values cannot be explained with classical models for optical outcoupling. Here, we analyse the role of photon recycling (PR) in assisting light extraction from perovskite light-emitting diodes. Spatially-resolved photoluminescence and electroluminescence measurements combined with optical modelling show that repetitive re-absorption and re-emission of photons trapped in substrate and waveguide modes significantly enhance light extraction when the radiation efficiency is sufficiently high. In this manner, PR can contribute more than 70% to the overall emission, in agreement with recently-reported high efficiencies. While an outcoupling efficiency of 100% is theoretically possible with PR, parasitic absorption losses due to absorption from the electrodes are shown to limit practical efficiencies in current device architectures. To overcome the present limits, we propose a future configuration with a reduced injection electrode area to drive the efficiency toward 100%.

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